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[0001] The invention relates to a method for determining the target position sound of a target of the genus defined radiating in the water in the preamble of Claim 1.

[0002] With a prior art method of this type (DE 37 05 695 c1) with small electroacoustic transducers, there sensor of mentioned, equipped sound receivers, there sonar receivers mentioned, in a first water depth the arranged and a first approximate value of the run differences of the sound between the direct propagation path and an indirect propagation path with surface reflection become a first time certain. Subsequent moved itself the sound receiver with a velocity into a second water depth and a second approximate value of the run time difference of the sound between the direct propagation path and an indirect propagation path with surface reflection to a second time certain. On the basis of the two approximate values for the run time differences, an approximate value for the velocity of the sound receiver and the time interval between first and second time an approximate value for the target distance becomes estimated and from it an approximate value for the goal-deep derived.

[0003] With one the bottom term "Pingstealing" prior art method, the one active sound impulses radiating target - like it e.g. an active locating torpedo sonar of a torpedo represents - (US 4,312,053), becomes by means of a dipped sound receiver of the angles of incidence of the acoustic energy within a sound impulse as function of time measured presupposes. These data become then in multi-way angles of incidence and multi-running away time differences reacted and thus a mathematical set of equations the calculation of the target distance and goal-deep dissolved.

[0004] The invention is the basis the object to create a method that initially mentioned type also also from the target of wide-band radiated acoustic energy, like e.g. Drive noises itself of a moving target, without additional conditions, like e.g. a horizontal and a vertical movement of the sound receiver, in particular in shallow water areas of very accurate results during the goal measurement supply.

[0005] The object is according to invention 1 dissolved by the features in the claim.

[0006] The invention process has the advantage that by the formation of the group signals purposes of a direction-controlled raising of the utilizable breakdown ratio (SNR) and by the evaluation of the run time differences between different propagation paths, contained in the group signals, by means of comparison with a model acceptance of sound propagation also with small water depths the target position becomes due to the noises reliable accurate certain radiated of the target. Already with simple geometric spread models for the sound the target position with very much high probability can become certain. With the knowledge the goal-deep can be corrected beyond that the azimuthal pinpointing angles of the target with a calculable elevation angle of the sound idea and to be restricted so the tolerance area of the target position. The method is also in the attitude to detect a target and determine the target acquisition, if the direction-selective formation of the group signals continuous over the entire azimuth performed will and on all group signals the signal processing according to invention applied becomes. Of course the method is more applicable also with targets, which send active sound impulses.

[0007] Convenient embodiments of the invention process with favourable developments and embodiments of the invention result from the other claims.

[0008] The balanced one between model and measurement can take place on different planes, whereby the degree of the conformity is a measure for the probability density of the target in the assumed target position, which is characteristic by bearing, removal and goal-deep.

[0009] With a prefered embodiment of the invention a direct comparison of the model and measuring run time differences becomes performed, as used as criterion the sum of the minimum spacer squares of the model run time differences becomes their next neighbors in the amount of the measuring run time differences. The predetermined degree of the conformity is achieved if the sum of these minimum spacer squares lies within a Konfidenzintervalls.

[0010] In accordance with a favourable embodiment of the invention thereby the minimum spacer squares before accumulation with a weighting factor become like multiplied, whereby as weighting factor like a power of the number nB, NO with the reflectance factors RO in the propagation path in accordance with i
“(1)” like = R< n> BB. RO <n> O
used becomes. The reflectance factor RB at the ground B and the reflectance factor at the surface O of a sound channel limited by ground B and surface O becomes plausibly a 1 selected between 0 and. By this weight strong absorbed and identifiable measuring run time differences of higher order do not affect not falsifying the probability density.

[0011] The identification of the run time differences in each transducers formed group signal electrical from the electrical output signals of i, can take place after different methods. The group signals, also Beams mentioned, become by coherent superposition of the corresponding incident direction of the sound run timedelayed outputs formed.

[0012] In accordance with a favourable embodiment of the invention the autocorrelation function of the group signal becomes measured when running, and the measuring run time differences for the different propagation paths become predeterminable points of gate time gained by evaluation of the maximums of the autocorrelation function. Between two points of gate time a time interval lies, within whose the target moved on. Since the autocorrelation function of a wide-band signal with the bandwidth possesses B Nebenmaxima with removing amplitude in the distance DELTA t=1/B, adjacent major peaks, which mark the measuring run time differences, can be separated in the autocorrelation function only if the amplitudes of the Nebenmaxima sufficient fast drop, which conditional that the signal must be wide-band suitable.

[0013] In accordance with a prefered embodiment of the invention the identification of the run time differences contained in the group signal becomes made by means of a Cepstralanalyse. The real cepstrum is defined as Fouriertransformierte of the logarithm of the absolute value of the autospectrum of a signal
EMI5.1
whereby X (e< i omega t>) represents the Fouriertransformierte of the signal. To the definition of the autospectrum see. [2], side 50 FF. The run time differences contained in the autospectrum leave themselves in the Fouriertransformierten of the spectrum, thus in the cepstrum, on the basis which maximums arising there identify. To the identification of the maximums the lengths of the fourier transformation for the autospectrum play and its Fouriertransformierten a crucial role. The length of the autospectrum is the temporal coherence length of the signal therefore as large ones as possible to be, may not however not to exceed, since then the maximums in the cepstrum disappear again.

[0014] In accordance with an alternative embodiment of the invention the comparison of the model run time differences with the measuring run time differences can become in the manner made with the identification of the run time differences contained in the group signal by determination of the cepstrum of the group signal that with the model run time differences a model cepstrum formed will and model cepstrum and measured cepstrum become immediate compared with one another.

[0015] As models for sound propagation to the determination of the model run time differences due to goal position acceptance of the variety of known models for the multi-path propagation of the sound in a sound channel the suitable models are consulted. Such models are for example readable from [1].

[0016] In accordance with a favourable embodiment of the invention a simple geometric model in a shallow water area with the water depth is taken as a basis zw with planar waters soil and constant speed of sound profile. With a known depth CPU of the sound receiver and an assumed goal-deep zS and azimuthal target distance x the sound on time becomes tk for k expenditure-selects propagation paths in accordance with
“(3)” tk = 1 DIVIDED C< SQRT> x< 2> + zk <2>< /SQRT>
calculated, whereby C is the constant sound velocity and zk the path, which the sound in each

propagation path k exclusive in vertical direction puts back.

[0017] With such a simple geometric model already sufficient accurate results in the measurement of the target position of a detected target become achieved with small cost of computation.

[0018] In accordance with a favourable embodiment of the invention the radial velocity of the target becomes, i.e. with determined target position. the velocity component of the target directed on the receiver, and the frequency of the sound determined radiated of the target. For this the sound run times for the direct propagation path of the sound and for the selected indirect propagation paths of the sound, necessarily calculated with the determination of the model run time differences, become determined target positions and the group signal, in which the target was detected, invoked. Times, which correspond to the called sound run times, frequency spectrums become formed from the group signal. From the frequency spectrums receiving frequencies are selected, the differences of the receiving frequencies formed and the called sound run times associated. For an assumed frequency radiated of the target and for an assumed, radial velocity of the target too everyone of the called sound on times becomes doppler frequency shifts, short Doppler shifts, calculated and the differences of the Doppler shifts formed. The receipt frequency differences and the Doppler shift differences become compared with one another, and the calculation of the Doppler shifts with changed in each case goal frequency and/or radial target velocity and the comparison with the receipt frequency differences becomes repeated until a predetermined degree of the conformity results. The assumptions of goal frequency and radial target velocity, met for reaching this agreement degree, outputted become as true goal frequency and true radial target velocity.

[0019] This development of the invention process has the advantage that become obtained by pure passive detection additional goal parameters, which give valuable information on a possible threat by the target. With the determination of the goal frequency the target classified can become and with the radial target velocity the velocity found, with itself the target moved towards the receiver. This possible e.g. an early torpedo detection and - warning and the introduction of Abwehrmassnahemen due to the knowledge of the torpedo attack speed. If the active sonar of the torpedo is activated, then significant frequency lines in the frequency spectrums of the group signal, which correspond to the doppler-shifted transmitter frequency of the Aktivsonas, result, whereby the Doppler shifts are different over the different sound propagation ways.

[0020] With not activated torpedo sonar that is detected torpedo due to its specific drive noise and its target position from measuring run time differences and model run time differences certain. In the frequency spectrums of the group signal belonging to to the target position significant high frequency frequency bands arise, whose center frequency with sufficient accuracy informations give over the Doppler shift contained in it to the determination to the radial target velocity.

[0021] In accordance with a prefered embodiment of the invention the Doppler shift in the direct propagation path of the sound becomes certain as product from assumed goal frequency and assumed radial target velocity divided by the sound velocity in the water. The Doppler shifts for the selected indirect propagation paths become from the ratio of the run time over the direct propagation path when running calculated over the respective indirect propagation path multiplied with the Doppler shift for the direct propagation path.

[0022] In accordance with an other favourable embodiment of the invention the position determination of the target is improved and the determination of the velocity of the target without a frequency analysis possible. The sound spreading from the target is absorbed on the direct propagation path to the receiver to few, since its path is shortest and losses do not arise by reflectances. The sound dependent different the corresponding Doppler effect temporal of the propagation path with an approximation of the target is tossed by the velocity of the target, so that in the distance of the run time differences the Doppler shift of the radiated sound is largest different and to the direct received sound. This temporal upsetting or elongation of the sound at the receiving place, different in relation to the direct propagation, becomes according to invention during the run time regulation of the sound for each change of position of the target considered.

[0023] In the model a model S dipping factor dependent of the velocity becomes for each propagation path for the next assumed position of the target provided. The estimate of the next assumed target position a way interval traveled during a time interval with an assumed velocity becomes added and the model run time differences and their temporal derivatives certain the already certain target position, which form the model S dipping factors. They correspond to the relative Doppler shift and become for different velocities from the previous position for assumed positions for each propagation path from the time variation of the model run time differences calculated and the model run time differences associated.

[0024] The point of gate time, to which the position target of the already determined became, the group signal with the largest level becomes within a time interval stored and the direct propagation path associated. Its Doppler shift remains constant if during the next two time intervals the velocity target on the direct propagation path as constant assumed becomes. Providing pattern signals the stored group signal becomes in each case with that model S dipping factors modulated, as the time course becomes by different destaging times tossed or stretched. For each assumed velocity and target position becomes for each propagation path a pattern signal created.

[0025] To the next point of gate time that is cross-correlated instantaneous received group signal with the pattern signals, which became from the group signal of the previous point of gate time gained. Each cross correlation function, which can take place in the Zeitoder frequency range, supplies a measuring run time difference, which corresponds to the model run time difference with the propagation path coincident with the pattern signal. The assumed velocity is at the same

time the same velocity of the target, with which it has the new position occupied, if all measuring run time differences and model run time differences for all propagation paths lie on top of each other and the comparison between measurement and model exhibits the smallest deviation.

[0026] The advantage of the development according to invention consists of the fact that also the error known by the Ambiguityfunktion during the run time regulation, which arise by the upsetting or elongation of the received group signal opposite the radiated sound by the provision of the pattern signals reduced become. By the temporal elongation or upsetting of the stored piece of time of the group signal, which is to be assigned to the direct propagation path, a pattern signal becomes provided, which is time-moderate matched on the sound received over the detour frequency and. Only with conformity the cross correlation functions maximums supply. If pulses are received, the elongation and upsetting of the pulse length become for each propagation path already considered by the creation according to invention of the pattern signals.

[0027] The advantage of the invention process consists of the fact that can become wide-band determined without frequency measurement alone from the temporal upsetting or elongation of the transmitted sound wave explainable with the Doppler effect the velocity of the target, since the model S dipping factors for the different propagation paths become dependent of the sound channel and a predetermined speed calculated.

[0028] For a classification of the target the advantage exists to determine from the relative Doppler shift, which the model S dipping factor indicates, and the velocity of the target the frequency or the frequency band of the sound without frequency analysis, radiated of the target.

[0029] An other improvement, in particular with an approximation of the target, consists of the fact that switched starting from a predeterminable target distance of wide-band evaluation of the group signal can become on an evaluation within a Frequenzbreichs with predeterminable center frequency and bandwidth and thus the utilizable/breakdown relationship is improved. In particular in the middle and upper frequency range, which will receive good at close range despite the higher attenuation can, the Doppler shift for the different propagation paths is significant different, so that the determination of the maximums of the cross correlation function for the different propagation paths supplies unique results and so that the position and Gerschwindigkeitsbestimmung is improved. Further the advantage exists that by the bandwidth the resolution of the ranging can become and by the integration time with the cross correlation function the resolution of the speed measurement dependent by a wrong alarm rate set. The distance resolution is the better, the per large bandwidth is, while the dissolution of speed with rising integration time grows. At least during the integration time and the time interval the velocity constant and the transient characteristic of the sound channel stable must remain.

[0030] The invention is more near described on the basis an embodiment illustrated in the

drawing in the following. Show:

Fig. 1 a block diagram of a circuit arrangement to the explanation of the method for determining the target position of a sound-radiating target,
Fig. 2 a diagram of an autocorrelation function of a group signal to the determination of the measuring run time differences,
Fig. 3 a diagram of a cepstrum of the same group signal to the determination of the measuring run time differences,
Fig. 4 a graph of a geometric sound propagation model with calculation of the sound on times in the single propagation paths,
Fig. 5 a block diagram of one opposite Fig. 1 modified circuit arrangement,
Fig. 6 opposite the block diagram in accordance with Fig. 1 extended block diagram to the explanation of the method for determining the goal parameters: radial target velocity and goal frequency after determined target position and
Fig. 7 opposite the block diagram in accordance with Fig. 1 block diagram extended for the determination of measuring run time differences.

[0031] With that subsequent on the basis the block diagram in Fig. 1 described methods for determining the target position sound of a target from a goal-far, submerged sound receiver, radiating in the water, becomes the fact exploited that in the water due to temperature stratifications or due to only limited water depth sound channels form, in those the sound on different, reflection-conditional propagation paths different length spreads and thus after different run times at the sound receiver arrives, so that a reception signal received of the sound receiver contains temporal superposition of the same signal. A target is e.g. each sound source located in the water, like it. by the prime movers or other noise-producing work aggregates of a surface ship, a submarine or a torpedo formed becomes. The sound emitted of these machines and aggregates is wide-band. In addition, the sound source can be an active sending sonar, which is installed in a surface ship, a submarine or a torpedo and in the water radiates sound impulses.
The sound receiver 10, on a platform diving in in the water, e.g. a submarine, installed, exhibits in known manner a plurality of electroacoustic transducers 11 is, those in the embodiment of the Fig. 1 a linear antenna e.g. form, like it. when trailing antenna (Towed array) becomes or used as side antenna (Flank array), fixed at the bottom structure, every now and then also as Bordwandstreamer referred, with submarines.

[0032] The electrical output signals of the transducers 11 become in known manner added by means of a Beamformers or a Richtungsbildners 12 direction-selective group signals. For this in such a manner the outputs of the transducers 11 time or phasedelayed, in the Richtungsbildner 12 become that bottom consideration of the desired idea or Peilrichtung &thetas; m all reception signals of the transducers 11 konphas are. The delay times rope n, m become for each transducer 11 for a predetermined Peilrichtung &thetas; m of the delay computer 23 for the order provided. In each Peilrichtung &thetas; m of obtained konphasen outputs become in the Richtungsbildner 12 added and into a memory 13 in association the respective Peilrichtung &thetas; m deposited.

A level detector 14 determined from the levels of the stored group signals the largest levels and gives those to the largest levels of the group signals associated Peilrichtungen &thetas; m as target acquisitions &thetas; Z out, which become a display device 15 supplied and in this numerical and graphic shown.

[0033] For a target acquisition with the pinpointing angle &thetas; Z is picked out from the memory 13 the associated group signal, and to the determination of the target position the bottom pinpointing angle &thetas; Z detected target this group signal of a signal processing are as follows submitted:

[0034] In the group signal the run time differences between the direct propagation path of the sound and the indirect propagation paths of the sound between the target and the sound receiver 10, resultant contained in the group signal, by reflectances in the sound channel, become as measuring run time differences tC, k measured by means of a run time analysis in the signal processing block 16. In a model block 17 those become certain are by an assumed target distance x and an assumed goal-deep zS, the run time differences between the direct propagation path and selected indirect propagation paths of the sound from the target to the sound receiver 10 as model run time differences TM, i certain by means of a selected model of sound propagation in a sound channel for an assumed target position. The measuring run time differences from the signal processing block 16 and the model run time differences from the model block 17 become a comparison logic 18 supplied. In the comparison logic 18 the model run time differences with that become measuring run time differences compared. If the comparison does not result in one sufficient degree of the conformity, then the determination of the model run time differences in the model block becomes 17 repeated with a changed goal position acceptance, and the new model run time differences become again compared with the measuring run time differences. For this in each case a goal position default model becomes 22 19 activated of the comparator, that the new goal position acceptance of the comparison logic 18 and a gate 21 supplied. This procedure becomes repeated until the comparison of the model run time differences with the measuring run time differences results in a sufficient degree of the conformity. If this is the case, then the gate becomes 21 opened and the goal position acceptance met for reaching this agreement degree last as genuine target position with the target distance xZ* and the goal-deep zS* to the display device 15 outputted and shown numerical graphic in the display device 15 and of the comparator 19.

[0035] The comparison logic 18, those by comparison of the model and measuring run time differences the probability density of the target at the assumed target position determined, can work after different algorithms. In the embodiment the comparison logic 18 works after the lease Square method. The probability to find with the assumed target position the target is reverse proportional thereafter to the sum of the smallest spacer squares of the model run time differences and the measuring run time differences. First the number of Nm of the run time differences fixed which can be considered becomes, those by the signal Noise reason (SNR) of the group signal, by the maximum number of the indirect propagation paths among other things in the model depends. Then i becomes that run time tmin (i) sought, any measuring run time

difference tC, k next comes for each model run time difference TM. i is the index of the model run time differences and k the index of the measuring run time differences. The mathematical expression for this is
"(4)" tmin (i) = tk
with
"(5)." k = badly min <FENCE TYPE=BAR> TM, i - tC, k< /FENCE>

[0036] The function bad min supplies the argument, i.e. the index k for that the term on the right side of Gl. (5) minimum is, here thus the index k of a measuring run time difference with minimum distance to a model run time difference.

[0037] Finally the sum of the minimum spacer squares becomes over all model run time differences in accordance with:
EMI17.1
formed. The minimum of K (zS, x) supplies target distance and goal-deep.

[0038] The sum K (zS, x) of these smallest spacer squares becomes in a comparator 19 with a Konfidenzintervall AI compared. If K (zS, x) does not lie within this Konfidenzintervalls AI, then a new goal position acceptance with a new goal-deep becomes zS and target distance x triggered of the comparator 19 in the block 20, which becomes the model block 17 supplied and leads a new calculation of the model run time differences for the new goal position acceptance. In the comparison logic 18 again the sum K (zS, x) of the smallest spacer squares becomes formed and in the comparator 19 with the Konfidenzintervall AI compared. If the sum K (zS, x) of the smallest spacer squares finally lies within the Konfidenzintervalls AI with a selected goal position acceptance, then the gate becomes 21 opened of the comparator 19, and the goal position target hit last becomes goal-deep as genuine target position with the target distance xZ* and zS* the display device 15 supplied and there graphic and numerical shown.

[0039] Alternative ones to the check with a Konfidenzintervall can become the sums of the minimum spacer squares in probabilities converted and a 2D or a 3D-Plot for the probability density certain become. A measure for the probability density P (zS, x) of a target in the assumed target position is the reciprocal value of the sum K (zS, x) of the minimum spacer squares. Ever small K (zS, x) is, the larger is the probability that the target is with the assumed coordinates x, zS the target position. The sum must become still in such a manner normalized that the spatial integral over all probability-dense and/or. the sum over all P (zS, x) same 1 is, therefore applies
EMI18.1

[0040] After this normalization the probability-dense per surface in the target area can become shown for the variety of the assumed target positions. An algorithm or an operator can recognize in the representation whether an ambiguous situation with several local maximums and potential target positions is present or whether the situation unique is.

[0041] In order to reduce the influence of strong absorbed not identifiable measuring run time differences of higher order unique by the run time analysis, the minimum spacer squares before accumulation with a weighting factor become like weighted in the comparison logic, which becomes 22 generated in the block. The weighting factors, the dependent are from the number of the Schallreflexionen in indirect propagation paths, can direct from the sound propagation model deposited become. At a subsequent still described simple sound propagation model for example reflectances of the sound with the reflectance factor R in each indirect propagation path take place, whereby the amplitude of the sound wave itself around the factor R< n> reduced. Since the Reflextionsfaktor RB at the ground and the reflectance factor RO at the surface of the sound channel different are, the weighting factors sit down like in each propagation path i from the part with ground reflection and from the part in accordance with surface reflection
"(1)" like = R< n> BB. RO <n> O
together, whereby nB the number of the ground reflections and NO is the number of surface reflections. For the reflectance factors RB and RO will become plausible values between 0 and 1 used, the A priori fixed. For example the reflectance factor RB = 0.5 and the reflectance factor RO = 0.75 becomes fixed. With two ground reflections and a surface reflection in q-ten propagation path would arise a weighting factor wq = 0.1875 with that the minimum spacer square (TM, q - tmin (q))<2> the propagation path i=q multiplied will would have.

[0042] The run time analysis to the determination of the measuring run time differences contained in the group signal can become on many way made. In a first embodiment the autocorrelation function of the group signal becomes formed when running. Such a formation of the autocorrelation function is in [2] described. The autocorrelation function consists during multi-path propagation of a superposition of autocorrelation functions, which are shifted around the differences of the relative run times in each case. These run time differences can become by evaluating the maximums of the autocorrelation function of the group signal certain, whereby become considered due to the symmetry of the autocorrelation function only positive run time differences. In Fig. 2 is such an autocorrelation function shown. Significant one is to be seen a maximum with a run time difference 0 ms, which correspond to the direct sound propagation way. Other maximums are with 2 ms to find 8 ms and 10 ms the run time differences between the direct propagation path and two indirect propagation paths as well as between the two indirect propagation paths define. The maximums are with DELTA t1,2, DELTA t1,3, and DELTA t2,3 characterized.
Prefered one becomes when running in the signal processing block 16 a Cepstralanalyse on the group signal applied and the measuring run time differences by evaluation of the maximums in the cepstrum gained. The Cepstralanalyse is actual known and in [3] described. The real cepstrum defined is as already mentioned as Fouriertransformierte of the logarithm of the absolute value of the autospectrum of the group signal in accordance with Gl. (2), whereby X (e< i omega t>) represents the Fouriertransformierte of the signal. The run time differences can be identified in the maximums of the cepstrum easy. An example of a cepstrum gained from a Cepstralanalyse is in Fig. 3 shown. The run time difference DELTA t1,2 between the direct propagation path and a first indirect propagation path is to be found with 2 ms. The run time difference DELTA t1,3 between the direct propagation path and a second indirect propagation

path amounts to 10 ms, while still another run time difference becomes DELTA t2,3 between the first and second indirect propagation path by the maximum with 8 ms identified. A comparison with the autocorrelation function in accordance with Fig. it shows 2 that these run time differences in equal size are to be found also in the autocorrelation function. In the cepstrum the maximums can be identified however substantial easier, because no Nebenmaxima emerges here - cannot like this in the autocorrelation function the case actual and thus real maximums by present reflectances with Nebenmaxima be confounded.

[0043] As models for the creation of the model run time differences can become from already known models corresponding suitable selected and in the presented method used. In [1] or [5] different models indicated are, those if necessary. with corresponding adaptation or modification used to become to be able. A likewise suitable sound propagation model is the bottom name “RAY” known and in [4] described. In addition, the use of a simple geometric sound propagation model, which becomes in the following described, shows already right good results in the accuracy of the determination of a target position.

[0044] In Fig. 4 is in a shallow water area of e.g. a water depth of approx. 200 m formed sound channel, in which a target S in a goal-deep zS and a sound receiver E in the receipt-deep CPU arranged are, and from each other a removal x exhibit themselves, schematically illustrated. With O the water surface is and with B the ground of the sound channel referred. The ground B becomes assumed as planar and the speed of sound profile of the sound channel as constant with the constant sound velocity C. The sound radiated of the target S arrives once at direct propagation path at the receiver E and on the other hand on indirect propagation paths by reflectances at the surface O and at the ground B at the receiver E. The direct propagation path is in Fig. 4 taken off with the atomic number k = 1 referred and shown. The indirect propagation paths are in Fig. 4 with k = 2 to k = 5 referred, whereby the paint-lined propagation path k = 2 paint-lines a reflectance of the sound at the water surface O and represented indirect propagation path k = 3 a reflectance of the sound at the ground B contains. The two other dash-dotted and dotted represented indirect propagation paths k = 4 and k = 5 contain in each case a reflectance the sound at the water surface O and at the ground B.

[0045] The path, which the sound in each of the chewing spreading ways must put back and tk < C amounts to, can become by assumption of corresponding mirror goals S' and S " or mirror receivers E' and E " for the different orders of the propagation paths calculated. The geometry for the calculation of the indirect propagation path k = 4 is in Fig. 4 by the represented rectangular triangle, whose Hypothenuse becomes between the mirror goal S' and the mirror receiver E " extended and its a side of the removal x formed, lifted out. General calculated itself the run time tk for each of the chewing spreading ways in accordance with Gl. (2) too
“(3),” tk = 1 DIVIDED C< SQRT> x< 2> + zk <2>< /SQRT>
whereby zk the path is, which the sound exclusive in vertical direction must put back. In Fig. 4 is the calculation of the value zk for the propagation ways k = 1 to k = 5 indicated. The elevation angle PHI k of the sound direction of arrival at the receiver E during sound propagation over the propagation paths k calculated itself too

"(8)" tan PHI k = zk DIVIDED x
and can to the correction of the measured pinpointing angle &thetas; Z used become. The angle of incidence of the sound incoming over the propagation path k = 4 at the receiver E is in Fig. 4 with PHI 4 shown.
By means of the geometric model the run times become tk for selected propagation paths of the sound in the sound channel certain with default of an assumed target distance x and an assumed goal-deep zS. The run time differences TM, i become by subtraction of the run times T1 for the direct propagation path k = 1 1 gained large of the respective indirect propagation path tk with k and - as described - the comparison logic 18 supplied.

[0046] In the case, in which the recovery of the measuring run time differences in the signal processing block 16 by means of Cepstralanalyse the cepstrum of the group signal formed becomes, the model used in the model block 17 can become going by extended that becomes formed with the model run time differences a model cepstrum. The comparison logic 18 becomes modified there that now no more become the single measuring run time differences of cepstrum and model compared with one another, but the immediate measured cepstrum with the model cepstrum.

[0047] With acceptance of an extended cost of computation can on separate goal detection and target acquisition by means of to the Fig. 1 described pinpointing plant to be done without and with the invention process also goal detection and the target acquisition performed become. One opposite Fig. 1 modified circuit arrangement for the so modified method is in the block diagram in Fig. 5 shown. In the circuit arrangement group signal latches and level detector were void and the predetermined angles &thetas; m for the instantaneous sound idea (Peilrichtung) is 21 placed together with the values for target distance x and goal-deep zS the goal position acceptance to the gate. In all other respects the method runs off in same way, as it to the Fig. 1 described is, whereby by change of the Peilrichtung &thetas; m in discrete angle angles the entire azimuth after targets is searched. As soon as the desired level of the conformity between the measuring run time differences and the model run time differences during a Peilrichtung &thetas; m achieved will and the comparator 19 the gate 21 opens, becomes also the Peilrichtung belonging to the genuine target position &thetas; m, then the genuine pinpointing angle &thetas; Z corresponds, to the display device 15 supplied there and together with the genuine target distance belonging to the genuine target position x* and genuine goal-deep zS* numerical and graphic shown.

[0048] That managing described methods can be consulted also for determining other goal parameters, after the target position found is. These goal parameters are the frequency of the sound, in the following goal frequency mentioned, radiated of the target, and the radial velocity of the target, that are the velocity component, with that itself the target on direct, i.e. radial, path on the receiver approaches, in the following radial target velocity mentioned. These additional method steps become on the basis in Fig. 6 of shown block diagram explained, whereby the block diagram in accordance with Fig. 1 complete in Fig. 6 integrated is and to that extent also the same reference numerals from Fig. 1 in Fig. 6 taken over is.

[0049] The block diagram of the Fig. 1 is first so that the run times tk the sound, extended with the fact, which become calculated with the sound propagation model in the model block 17 for the propagation paths, become continuous 24 written into a run time memory, whereby the run times calculated for a preceding target position become tk overwritten with the run times calculated for a subsequent target position tk in each case, so that in the run time memory 24 the run times calculated for the last assumed target position are always tk deposited. If the true target position is recognized, then the gate becomes 21 opened by the output of the comparator 19 and the true target distance xZ*, the true goal-deep zS* and the pinpointing angles &thetas; Z of the display device 15 supplied. Simultaneous one arrives the comparator signal as readout signal at the run time memory 24, so that the run times contained in the run time memory 24 become tk successively selected and a Fouriertransformator 25 supplied as control signal. In to Fig. 4 described embodiment is thus selected the run times tk with k=1 to 5. In the Fouriertransformator 25 the group signal becomes, with that the target acquisition &thetas; Z found is submitted of a fourier transformation, and for times, which correspond to the selected run times tk, the frequency spectrums formed. From the frequency spectrums the receiving frequencies are selected fEk in association to the run times tk, and in the Differenzbildner 26 the differences of the receiving frequencies become
"(9)" DELTA fiber plastic = fE1 - fEk
with k> 1 formed and in the memory 26 in association to the run times tk with k> 1 stored.

[0050] The run times selected from the run time memory 24 tk become a computer 28 supplied. The computer 28 is with a default module 29 for the goal frequency f0 and radial target velocity vR1 connected. In the computer 28 the Doppler shift becomes dfk calculated for each run time tk, whereby itself the Doppler shift for the direct propagation path in accordance with
"(10)" df1 = fo. vR1 DIVIDED C
and the Doppler shifts for the indirect propagation paths in accordance with
"(11)," dfk = df1. T1 DIVIDED tk
result in, whereby C is the sound velocity in the water and k the atomic number for all selected indirect propagation paths, those in the embodiment of the Fig. 4 same k=2, 3, 4, 5 amounts to. Further 28 from the calculated Doppler shifts dfk in the single propagation paths k become the differences in accordance with Doppler shifts in the computer
"(12)," DELTA FMk = dfk - df1
certain, whereby k is again the atomic number for the indirect propagation paths and thus> k 1. These Doppler shift differences DELTA FMk become 1 stored in a memory 30 in association the run times tk> with k. In a comparison logic 31 the receipt frequency differences DELTA fiber plastic and the Doppler shift differences DELTA FMk become those the same sound on times tk with k> 1 associated are, with one another compared. If the comparison does not result in one sufficient degree of the conformity, then the determination of the Doppler shift differences DELTA FMk in the computer becomes 28 with a changed goal frequency f0 and/or a changed radial target velocity vR1 repeated, and the new Doppler shift differences DELTA FMk become again with the receipt frequency differences DELTA fiber plastic compared. This procedure becomes repeated until the comparison of the Doppler shift differences DELTA FMk

with the receipt frequency differences DELTA F results in a sufficient degree of the conformity. If this is the case, then a gate becomes 32 opened, at which the last assumed or predetermined goal frequency f0 and the last assumed radial target velocity vR1 line up in each case. There with the opening of the gate 32 the assumptions of goal frequency f0 and radial target velocity vR1 of the display device, met last, become 15 supplied and as genuine goal frequency f0* and genuine radial target velocity vR1* graphic and numerical shown.

[0051] The comparison logic 31 works in same way as the before described comparison logic 18, e.g. after the lease Square method, whereby as criterion with the comparison of the receipt frequency differences DELTA fiber plastic and the Doppler shift differences DELTA FMk becomes the sum of the minimum spacer squares of the Doppler shift differences DELTA FMk their next neighbors in the amount of the receipt frequency differences DELTA fiber plastic used. As the comparison logic 18 also the comparison logic 31 still another here not represented comparator downstream can be, becomes compared in which the sum of the minimum spacer squares with a Konfidenzintervall. If the sum lies within the Konfidenzintervalls, then the predetermined degree of the conformity of the Doppler shift differences DELTA FMk with the receipt frequency differences DELTA fiber plastic achieved, and the comparator is the generated gate opening signal for the gate 32. If the sum lies outside of the Konfidenzintervalls, then the comparator signal releases a new default of goal frequency and/or radial target velocity in the default module 29.

[0052] Over a larger number from comparison values to obtained, without the number of the selected propagation paths and/or. the selected run times tk in the propagation paths to increase, only the differences of the receiving frequencies between the receiving frequencies do not become fEk with k> 1, which are the selected run times tk in the indirect propagation paths associated, and which receiving frequency fE1, which is the run time T1 of the direct propagation path associated, formed, but also the receipt frequency differences between the indirect propagation paths themselves formed, so e.g. the receipt frequency differences between the Empfangsfrenquenzen fE3 and fE2, which are the sound on time T3 over the propagation path of third order and the run time t2 in the propagation path of second order associated. In corresponding manner also the Doppler shift differences DELTA FMk between the indirect propagation paths formed and in the comparison logic become 31 compared with the corresponding receipt frequency differences in the described manner.

[0053] For an improvement of the determination of the target position and the determination of the velocity of the target with pattern signals the model in the model block becomes 17 in Fig. 1 for the determination of model S dipping factors sports club extended. For the calculation of the model run time differences tMi and the model S dipping factors sports club Fig becomes. 4 consulted and exemplarily the indirect propagation path k=3 with a reflectance at the ground considered, after the target S drove the position S* occupied to a first point of gate time with a velocity v in the direction of the receiver E and to the next point of gate time has. The run time over the direct propagation path k=1 amounts to:
“(13)” T1 = 1 DIVIDED C< SQRT> (x - v. t)< 2> + z1 <2>< /SQRT>

and for the propagation path over the ground
"(14)." T3 = 1 DIVIDED C< SQRT> (x - v. t)< 2> + z3 <2>< /SQRT>

[0054] The model run time difference TM amounts to
EMI30.1

[0055] The time variation of the model run time difference TM after the time t becomes 17 calculated in the model block and supplies the model S dipping factor sports club for the second point of gate time:
EMI30.2

[0056] The position of the target x determined to the first point of gate time, zS becomes used and sports club for different velocities v as well as the model run time difference in accordance with Gl. (15) TM certain.

[0057] The time variation of the model run time difference in accordance with Gl. (16) corresponds to a time variation of the phase ϕ with a frequency omega =2 pi f
"(17)" dϕ DIVIDED dt = omega DIFFERENTIAL TM DIVIDED DIFFERENTIAL t

[0058] The time variation of the phase ϕ an elongation or an upsetting of the time course of the group signal causes, which becomes by the velocity of the target the corresponding Doppler effect caused, and leads to a Doppler shift DELTA omega and a rotation of the phase ϕ the complex frequency spectrum with each frequency omega or the time course of the received group signal along each propagation path. The Doppler shift DELTA omega related to the frequency omega is the same model S dipping factor sports club and dependent from the velocity v of the target as well as the time t, in that itself the target with the velocity v moved.
"(18)" DELTA omega DIVIDED omega = DIFFERENTIAL TM DIVIDED DIFFERENTIAL t = sports club (v, t)

[0059] A group signal, which contains a pulse, receives likewise a relative upsetting or> elongation of the emitted pulse length, which is by the model S dipping factor sports club considered over the indirect propagation paths k 1. With that model S dipping factors sports club the piece of time of the group signal received to the first point of gate time is tossed and/or stretched and thus pattern signals manufactured.

[0060] Fig. 7 shows opposite Fig. 1 extended block diagram. The signal processing block 16 for the run time analysis is alternatively 12 connected by opening a switch 161 over a bandpass 162 of the center frequency omega with the memory 13 for the group signals at the Ausgag of the Richtungsbildners. The group signal becomes 16 supplied after detection of a target of an autocorrelation circuit 163 in the signal processing block, in that the autocorrelation function of the group signal formed and maximums with the measuring run time differences DELTA t1,2; DELTA t2,3; DELTA t1,3 evaluated become, as in Fig. 2 shown. The measuring run time

differences tCk in the comparison logic 18 with the model run time differences tMk compared and result in the target position x, zS to the first point of gate time. In addition the group signal becomes the same point of gate time in a sample signal circuit 165 concerning its size and stability examined and the time course of the group signal with the largest level and the largest stability within a time interval DELTA T stored. In the model block 17 patterns of the model S dipping factors sports club over the model run time differences TM of the target positions and velocities assumed to the next point of gate time become from the goal position and speed default model 22 calculated and provided. To the determination of pattern signals the stored piece of time of the group signal the corresponding determined model S dipping factors sports club is tossed or stretched, for example by different selection times of the stored time course. To the next point of gate time after the time interval DELTA T is correlated the received group signal with the pattern signals from the sample signal circuit 165 in a cross correlation circuit 166, whose integration time rope exhibits the equal length as the integration time in the autocorrelation circuit 163. The maximums determined with the cross correlation of all pattern signals with the group signal evaluated and with the model run time differences TM in the comparison logic 18 compared becomes determining measuring run time differences tk.

[0061] With conformity the values for the target position, predetermined in the goal position and speed default model 22, are connected through xZ*, zS* and the velocity v* over the gate 21 to the display device 15 and displayed.

[0062] Literature:

[1] Computational Ocean Acoustics, F. B. Jensen, W. A. Kuperman, M. B. Porter, H. Schmidt, AIP press American Istitute OF Physics, New York 1994, in particular S. 58,
[2] J. S. Bendat and A. G. Piersol “Engineering Applications OF Correlation at spectral analysis”, John Wiley and Sons, Inc. 1993.
[3] B. Bending ore, M. Healy and J. Tukey, “The quefrency alanysis OF time of series for echoes: Cepstrum, pseudoautocovariance, CROSS cepstrum and saphe cracking " Proc. Symposium time Series analysis, 1963, pages 209 - 243.
[4] Bowlin et al. “Ocean Acoustics Ray Tracing software RAY”, WHOI Technical report, WHOI-93-10. (ftp://oalib.saic.com/pub/oalib/ray)
[5] Sound Progation into the Sea, Robert J. Urick, Peninsula Publishing, 1982, ISBN 0-932146-08-2, in particular S. 8 - 11

Result Page

1. Methods for determining the target position sound of a target bottom evaluation of the sound radiated of the target, which will receive on direct propagation path and on indirect propagation paths resultant by reflectances from a submerged, goal-far sound receiver (10) with a number of electroacoustic transducers (11), radiating in the water, characterised in that the electrical output signals of the transducers (11) to group signals added become richtungselektiv that certain in the group signals by means of run time analysis run time differences of the sound between the direct propagation path and indirect propagation paths become as measuring run time differences that certain by means of a model of sound propagation for an assumed target position run time differences between the direct propagation path and selected indirect propagation paths from the target become to the sound receiver (10) and these Model run time differences with the measuring run time differences compared become that the determination of the model run time differences with changed in each case goal position acceptance becomes repeated until the comparison of the model run time differences with the measuring run time differences results in a predetermined degree of the conformity, and that the goal position target hit for reaching this agreement degree becomes as genuine target position outputted.

2. Process according to claim 1, characterised in that as criterion with the comparison of model and measuring run time differences the sum of the minimum spacer squares of the model run time differences to their next neighbors in the amount of the measuring run time differences used becomes.

3. Process according to claim 2, characterised in that the predetermined degree of the conformity achieved is if the sum of the minimum spacer squares lies within a Konfidenzintervalls.

4. Process according to claim 2, characterised in that the probability of the stay of the target in the assumed target position as reciprocal value of the sum of the minimum spacer squares determined will and that from the variety of the probabilities obtained for assumed target positions the Wahrscheinlichkeitsdichte per unit area of the target area certain is visited will and on the basis the Wahrscheinlichkeitsdichte potential target positions.

5. Process according to one of claims 2 - 4, characterised in that the minimum spacer squares before the accumulation with a weighting factor (like) multiplied becomes.

6. Process according to claim 5, characterised in that as weighting factor (like) a power of the number (nB, NO) of the reflectances with the reflectance factors (RB, RO) in the propagation path (i) in accordance with
like = RB <n> B. RO <n> O
used becomes, whereby the reflectance factor (RB) for a reflectance at the ground becomes plausible and the reflectance factor (RO) for a reflectance at the surface (O) one by ground (B) and surface (O) of limited sound channel between 0 and 1 selected.

7. Process according to one of claims 1 - 6, characterised in that when running the author correlation function of the group signal certain and the measuring run time differences by evaluating the maximums of the autocorrelation function gained will become.

8. Process according to one of claims 1 - 6, characterised in that when running a Cepstralanalyse on the group signals applied will and that the measuring run time differences become gained by the evaluation of the maximums in the cepstrum.

9. Process according to claim 1, characterised in that when running a Cepstralanalyse on the group signals applied and in each case the cepstrum of the group signal as measuring cepstrum formed will and that formed with the model run time differences a model cepstrum and the comparison of the measuring run time differences and the model run time differences become by immediate comparison of the model cepstrum with the measuring cepstrum performed.

10. Process according to one of claims 1 - 9, characterised in that as model a geometric model of sound propagation in a shallow water area with the water depth (zW) with planar waters soil and constant speed of sound profile at the basis placed becomes that with a known depth (CPU) of the sound receiver and an assumed goal-deep (zS) and an assumed azimuthal target distance (x) the run time (tk) for k of selected propagation paths in accordance with
tk = 1 DIVIDED C< SQRT> x< 2> + zk <2>< /SQRT>
calculated becomes, whereby C is the constant sound velocity and zk the path, which the sound in everyone puts back the k of propagation paths exclusive in vertical direction, and that to the recovery of the model run time differences the run time (T1) for the direct propagation path of the run times (tk) for k selected indirect propagation paths with k > 1 subtracted becomes.

11. Process according to one of claims 1 - 10, characterised in that the levels of the group signals certain and by evaluation of the largest levels of targets and the target acquisitions certain detects will and that only in those group signals measuring run time differences become certain and compared with model run time differences, in which a target was detected.

12. Process according to one of claims 1 - 11, characterised in that with detection genuine target

position with model sound propagation with determination model run time differences calculated run times sound for direct propagation path and for selected indirect propagation paths target position invoked will that from the group signal, in which the target was detected Frequenzsprektren that the called run times (tk) corresponding times formed to become that from the frequency spectrums receiving frequencies (fEK) selected, which become differences of the receiving frequencies (DELTA fiber plastics) formed and the called run times (tk) associated that for an assumed goal frequency (f0), radiated of the target, and for an assumed radial target velocity (vR) too everyone of the called run times (tk) a Doppler shift (dfk) calculated and the differences of the Doppler shifts (dfk) formed it becomes that the receipt frequency differences (DELTA fiber plastic) and the Doppler shift differences (DELTA FMk), which the same run times (tk) associated are, with one another compared become that the calculation of the Doppler shifts (dfk) with changed in each case goal frequency (f0) and/or radial target velocity (vR) becomes and the comparison with the receipt frequency differences (DELTA fiber plastic) repeated until a predetermined degree of the conformity results, and that the assumptions of goal frequency (f0) and radial target velocity, met for reaching this agreement degree, (vR) will spend as true goal frequency (f0*) and true radial target velocity (v*R1).

13. Process according to claim 12, characterised in that as criterion with the comparison of receipt frequency differences (DELTA fiber plastic) and Doppler shift differences (DELTA FMk) the sum of the minimum spacer squares of the Doppler shift differences (DELTA FMk) its next neighbors in the amount of the receipt frequency differences (DELTA fiber plastic) used becomes.

14. Process according to claim 13, characterised in that the predetermined degree of the conformity achieved is if the sum of the minimum spacer squares lies within a Konfidenzintervalls.

15. Process according to one of claims 12 - 14, characterised in that the Doppler shift (df1) in the direct propagation path as product from assumed goal frequency (f0) and assumed radial target velocity (vR1) divided by the sound velocity (C) in the water and the Doppler shift (dfk, k> 1) for the selected indirect propagation paths as the Doppler shift (df1) in the direct propagation path calculated, multiplied with the ratio of run time (T1)> in the direct propagation path and run time (TM, k 1) in the respective indirect propagation path, becomes.

16. Process according to one of claims 12,-15, characterised in that as receiving frequencies (fEk) of significant receipt frequency bands from the Freuquenzspektren to be selected and the goal frequency (f0) as a frequency band assumed radiated of the target becomes.

17. Process according to claim 16, characterised in that harmonics of the goal frequency in the drive noise to the classification of the target used becomes.

18. Process according to one of claims 1 - 11, characterised in that the time course of the group signal, in which a target is detected and a target position (x, zs) associated, within a time interval (DELTA T) stored will and for providing pattern signals with predeterminable model S dipping factors (sports club) stretched is tossed and/or that the model S dipping factor (sports club) for each model run time difference of the position assumed to the next point of gate time from the first target position and predeterminable values for the velocity of the target becomes certain that model S dipping factor (sports club) the model run time differences (tMi) associated become that the pattern signals with the group signal received to the next point of gate time in a time interval are cross-correlated and that the measuring run time differences (tk) by evaluating the maximums of the cross correlation function gained will become, with the model run time differences (tMi) compared and position and velocity of the target will supply.

19. Process according to claim 18, characterised in that the first target position with the measuring run time differences (tk) from the evaluation of the autocorrelation function determined becomes.

20. Process according to claim 18 or 19, characterised in that a time-dependent relative Doppler shift along the propagation paths from the model S dipping factors (sports club), belonging to the determined measuring run time differences, certain becomes.

21. Process according to claim 20, characterised in that from the relative Doppler shift (DELTA omega/omega) and the velocity v a target classification derived becomes.

22. Process according to claim 21, characterised in that center frequency and bandwidth of the group signal selected becomes.

23. Process according to claim 22, characterised in that the selection to the sound radiation matched which can be expected from the target to becomes.

24. Process according to claim 20 or 21, characterised in that the adaptation dependent from the removal to the target and/or time-dependently selected becomes.

25. Process according to one of claims 23 - 24, characterised in that the bandwidth to a desired distance resolution matched becomes.

26. Process according to one of claims 18 - 25, characterised in that the integration time (rope) for the cross correlation function and the dissolution of speed one on the other tuned becomes.